Elliptic Flow of ϕ-meson in Pb-Pb Collisions at $\sqrt{s_{NN}} = 2.76$ TeV

UNICAMP

ALICE

Outline

- Motivation
- A Large Ion Collider Experiment (ALICE)
- Flow analysis method
- ϕ-meson signal extraction
- Results
- Summary

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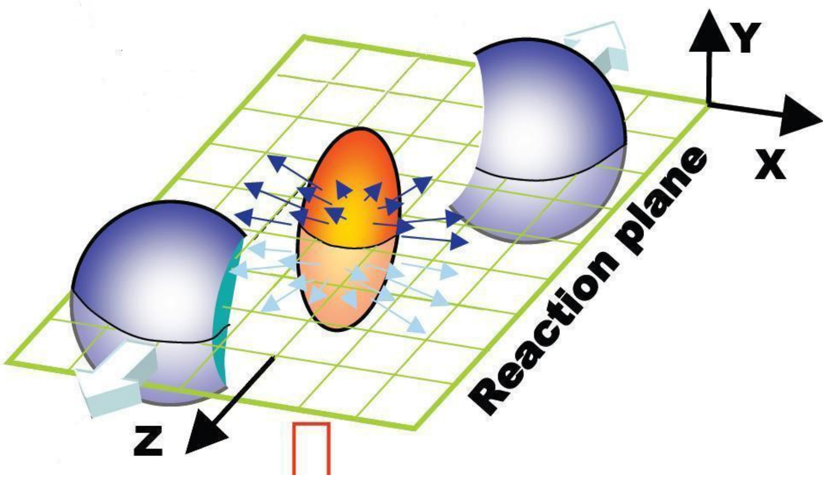
FAPESP

XI LISHEP 2013

❖ Motivation



$$E\frac{d^3N}{d^3p} = \frac{1}{2\pi}\frac{d^2N}{p_T dp_T dy} \times \left(1 + 2\sum_{n=1}^{\infty} v_n(p_T, y)\cos\left(n\left(\varphi - \Psi_R\right)\right)\right)$$

$$v_n = \left\langle \cos\left(n\left(\varphi - \Psi_R\right)\right)\right\rangle$$

- Azimuthal correlation with the symmetry plane (Ψ_R).
- Built up at early stage of the collision, and therefore provides information about the properties and evolution of the created system.

❖ Motivation: Quark number scaling of v_2 at RHIC

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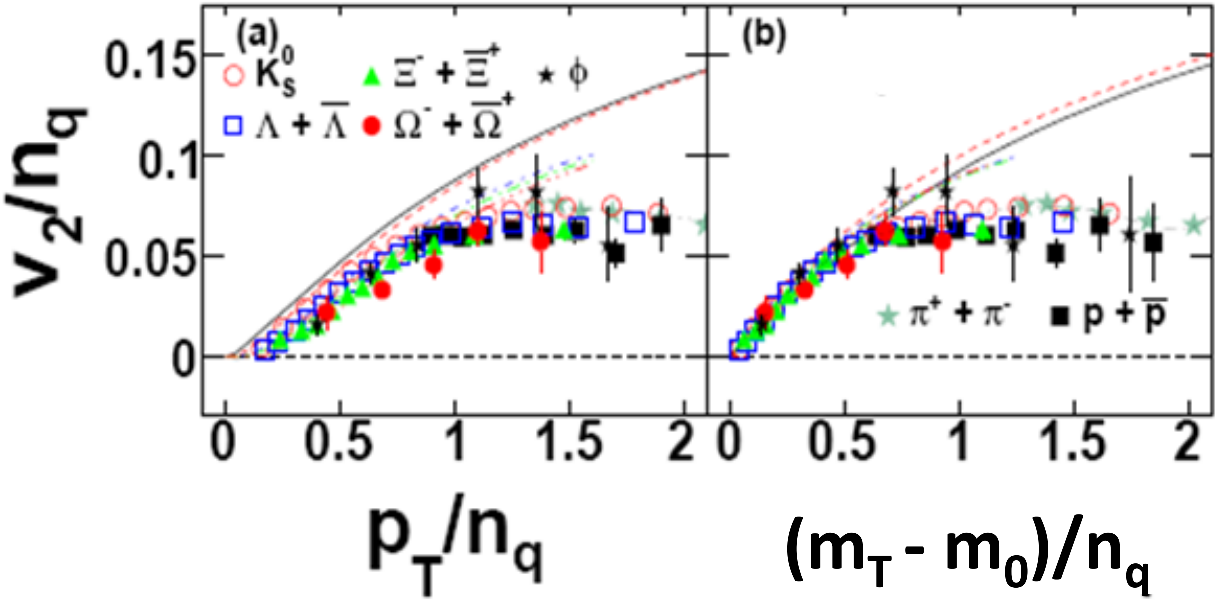


- Baryon and meson elliptic flow follow the number of constituent quark (n_q) scaling.
- Indicates that partonic flow builds up at RHIC.

Transverse mass : $m_T = \sqrt{p_T^2 + m_0^2}$, m_0 is the mass of the particle

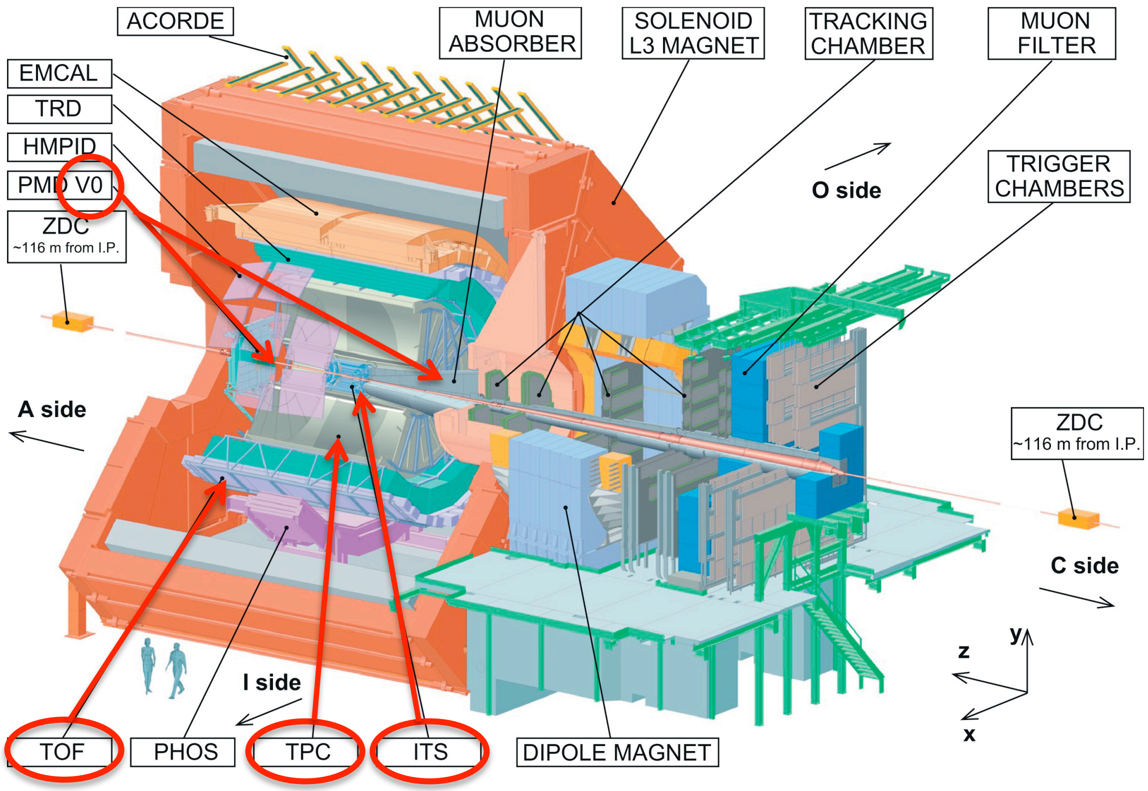
❖ Motivation: v_2 of ϕ-meson

- Carried a pair of strange quarks which are all produced in the collision.
- Assuming a small hadronic cross section ϕ-meson v_2 develops mainly at early times of the collision.

Mass	1019 MeV/c^2
Width (Γ_0)	4.26 MeV/c^2
Life time ($c\tau$)	41 fm
Quark content	$s\bar{s}$
Measured decay channel	$\phi \rightarrow K^+ + K^-$
Branching ratio	48.9 %

❖ ALICE (A Large Ion Collider Experiment)

For more detail see plenary talk by **Yiota FOKA**



- Main tracking detector: TPC (Time Projection Chamber)
- Vertex and tracking : ITS (Inner Tracker System)
- Centrality and event plane : TPC and VZERO
- Particle Identification : TPC and TOF (Time Of Flight)

DATA sample:

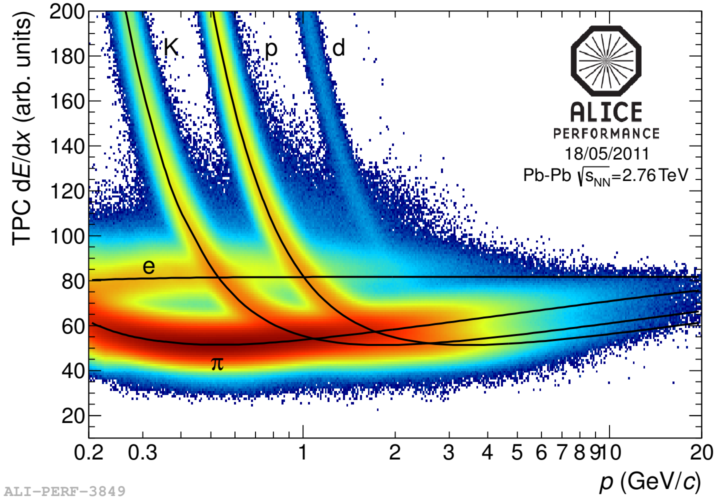
- Pb-Pb at $\sqrt{s_{NN}}$ = 2.76 TeV
- 2010 data
- ~ 16M events

Daughters :

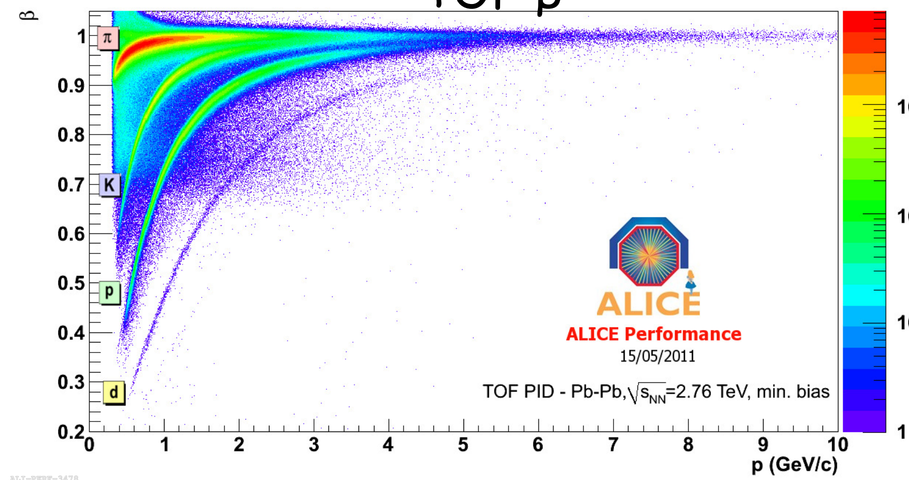
- Acceptance : psuedorapidity $|\eta| < 0.8$, Azimuthal angle $0 < \varphi < 2\pi$
- Transverse momentum $p_T > 200$ MeV/c

❖ Particle identification and Centrality determination

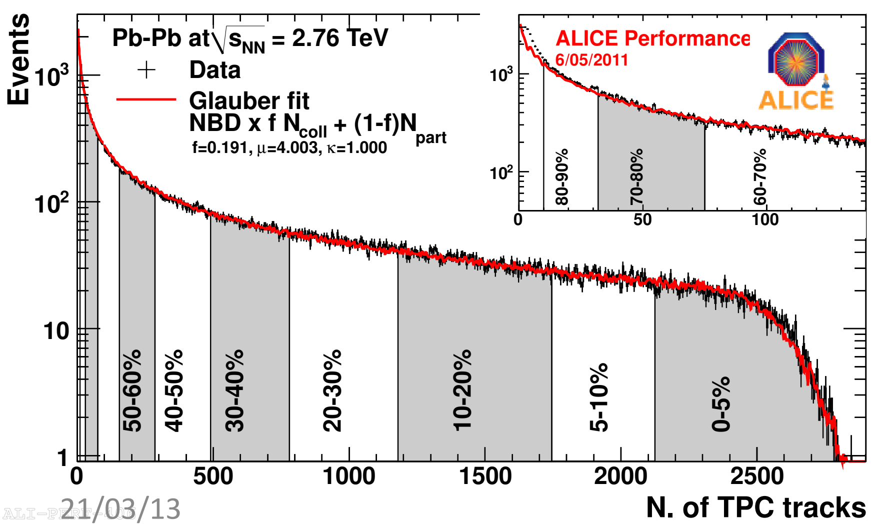
Energy loss in TPC



TOF β



Centrality determination with track multiplicity in TPC



➢ Charged pion, kaon and (anti-)proton identification using information on specific energy loss (TPC) and time of flight (TOF)

$$\beta = \frac{L}{ct}$$

L : track length from the collision vertex to the TOF detector

t : time of flight

❖ Flow analysis methods

➢ Event Plane (EP)

$$v_n^{obs}(\eta, p_T) = \langle \cos[n(\phi - \Psi_{EP})] \rangle$$

$$v_n(\eta, p_T) = v_n^{obs} / R_n$$

$$R_n = \langle \cos[n(\Psi_{EP} - \Psi_R)] \rangle$$

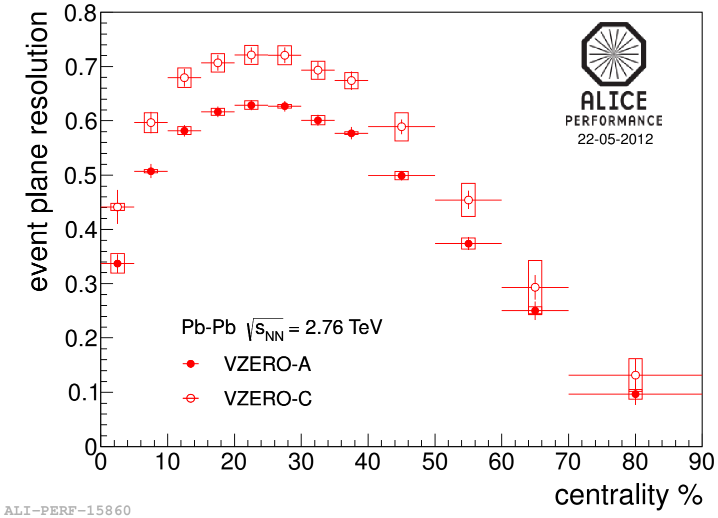
$$\Psi_{EP} = [\tan^{-1}(Q_{n,y} / Q_{n,x})] / n$$

$$Q_n = (Q_{n,x}, Q_{n,y})$$

$$Q_{n,x} = \sum_i w_i \cos(n\phi_i)$$

$$Q_{n,y} = \sum_i w_i \sin(n\phi_i)$$

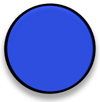
Event plane resolution from VZERO

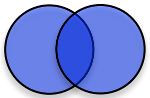


➢ Scalar product (SP)

$$v_n(\eta, p_T) = \frac{\langle Q_n u_n^*(\eta, p_T) \rangle}{2\sqrt{Q_n^a Q_n^{b*}}}$$

$$u_n = (\cos\varphi, \sin\varphi)$$





➢ Two-Particle cumulant

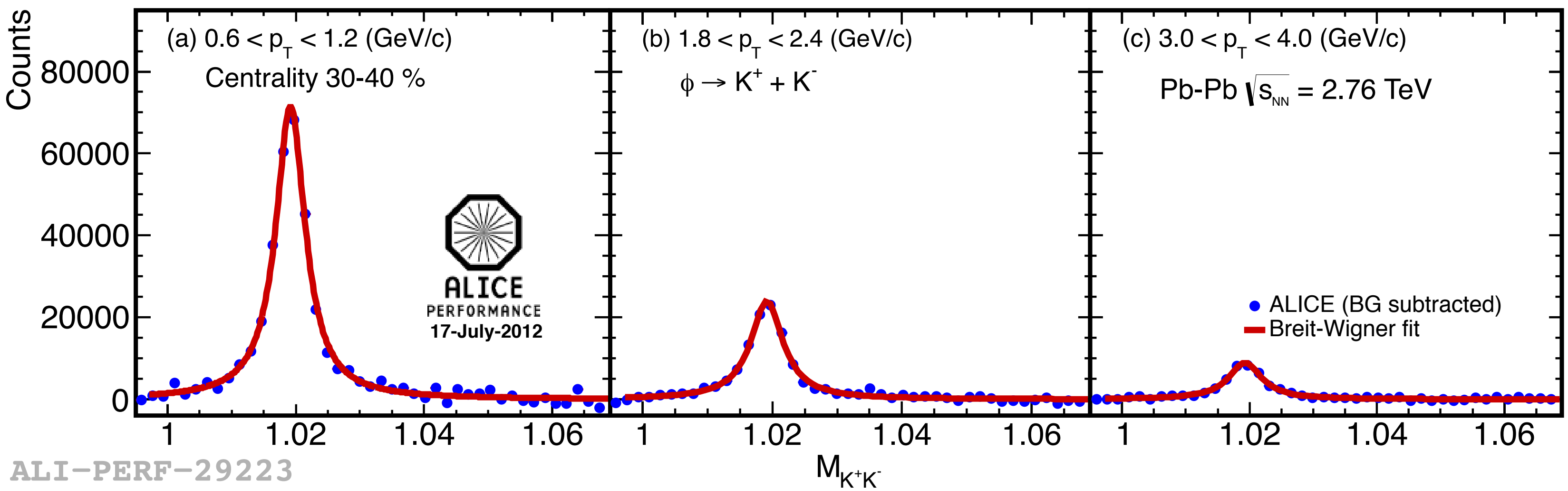
For elliptic flow n = 2

$$v_n\{2\} = \sqrt{c_n\{2\}} \quad \text{where } c_n\{2\} = \langle\langle 2 \rangle\rangle$$

$$\langle 2 \rangle = \frac{|Q_n|^2 - M}{M(M-1)}$$

M : number of particles

❖ ϕ-meson invariant mass yield



- The ϕ-meson yield vs. K^+K^- invariant mass (M_{K+K-}) is extracted by subtracting the distribution for the same-sign kaon pairs.

- Breit Wigner parameterization of the ϕ-meson (S) yield

$$\left[\frac{\Gamma_0}{(M_{k^+k^-} - m_0)^2 + \frac{\Gamma_0^2}{4}} \right]$$

- Background (B) : 2nd order Polynomial $A + BM_{k^+k^-} + CM^2_{k^+k^-}$

❖ v_2 vs. invariant mass method

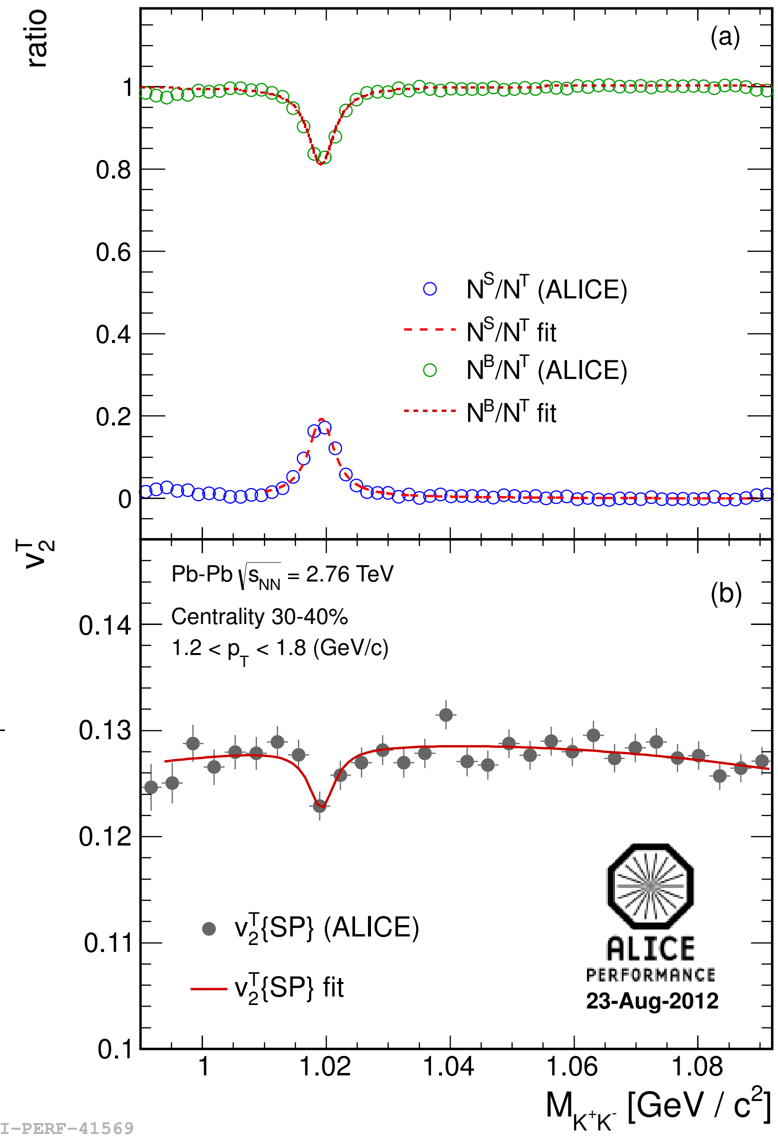
- Measure v_2^T of ϕ-meson candidates vs. invariant mass in a given bin of p_T, η and collision centrality.
- Fit v_2^T Vs Invariant mass using

$$v_2^T(M_{k^+k^-}) = v_2^S \frac{N^S}{N^S+N^B}(M_{k^+k^-}) + v_2^B \frac{N^B}{N^S+N^B}(M_{k^+k^-})$$

Where $v_2^B(M_{k^+k^-}) = p_0 + p_1 M_{k^+k^-} + p_2 M_{k^+k^-}$

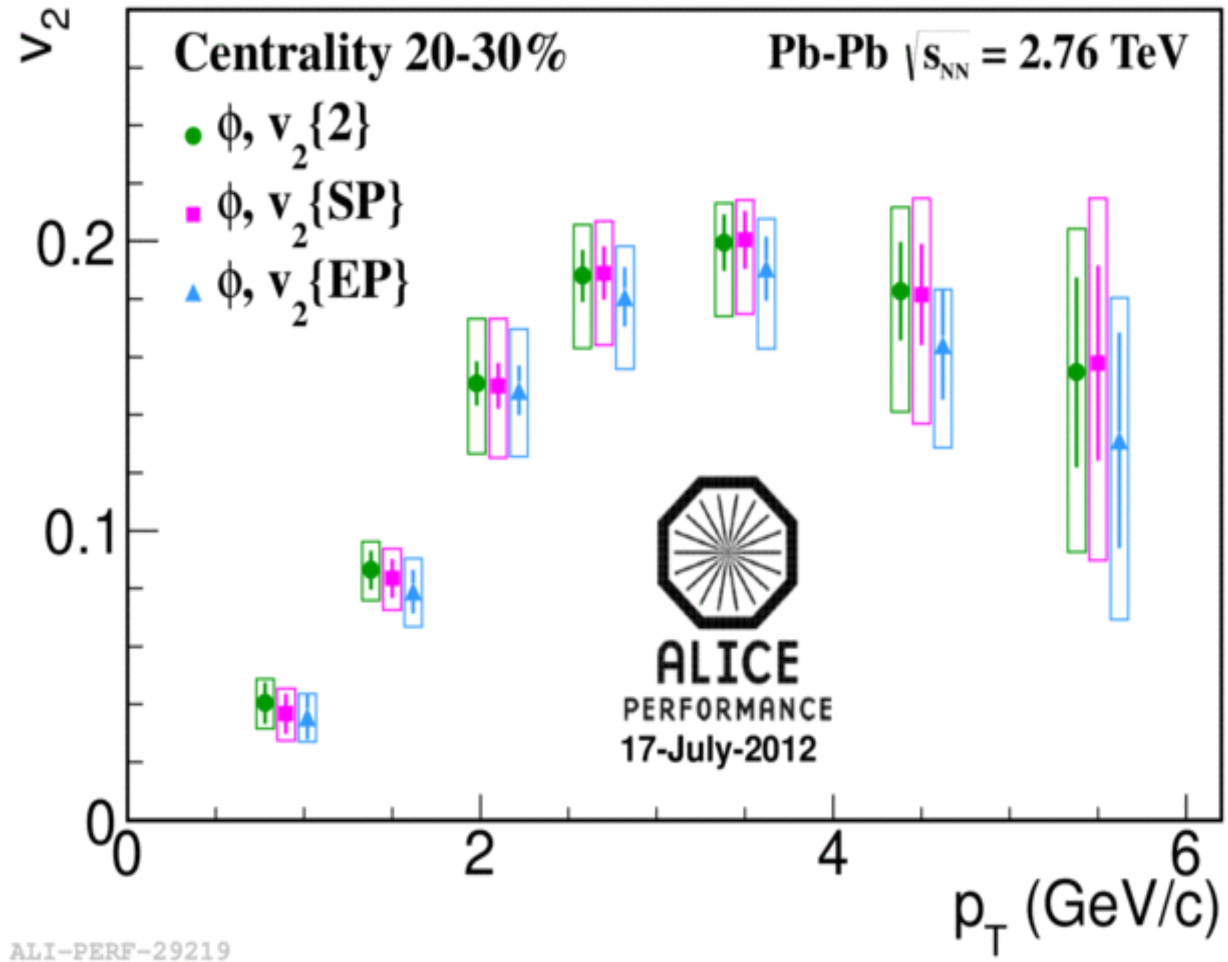
N^S and N^B : Signal and background yields

$N^T = N^S + N^B$



Borghini et al. Phys. Rev. C70 (2004) 064905

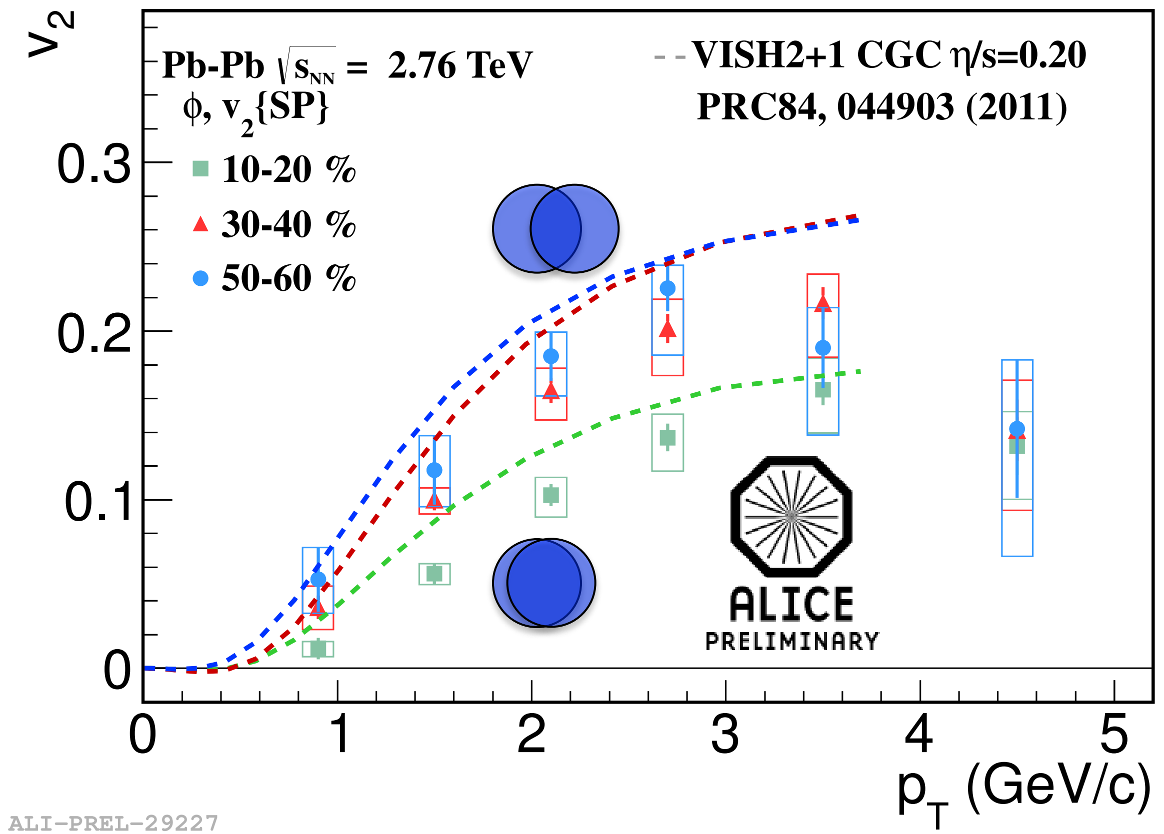
❖ Comparison between different methods



➢ Good agreement between the three methods

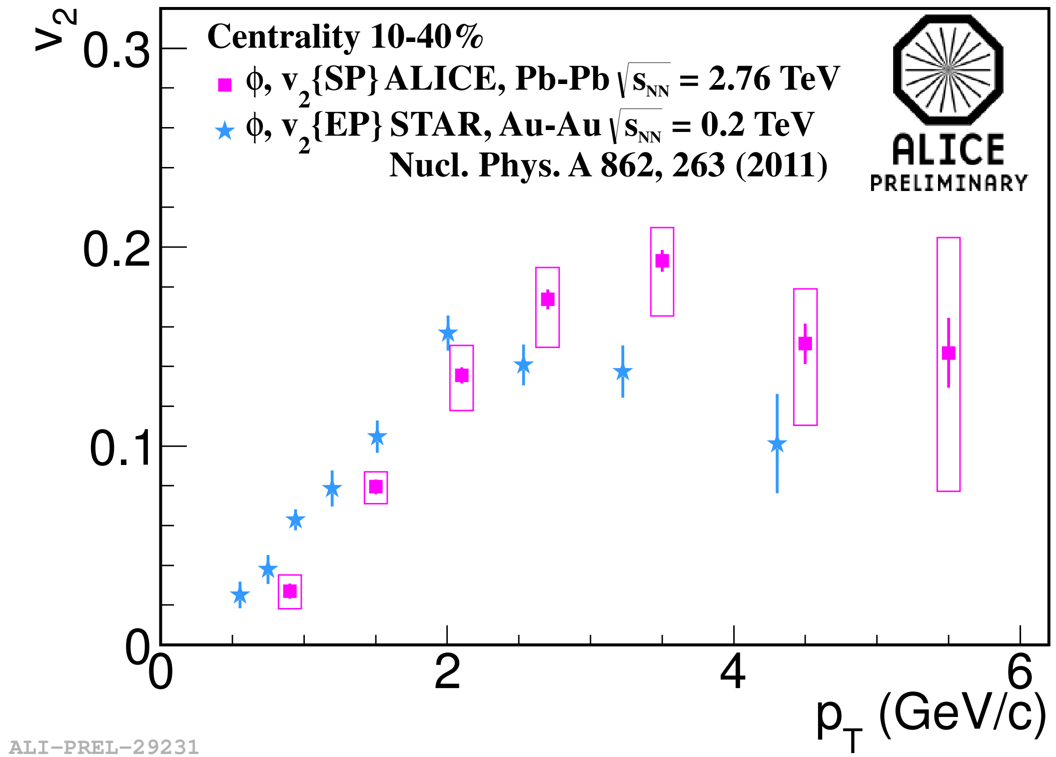
bars: statistical uncertainty
boxes: systematic uncertainty

❖ Results: ϕ-meson $v_2(p_T)$ as a function of centrality



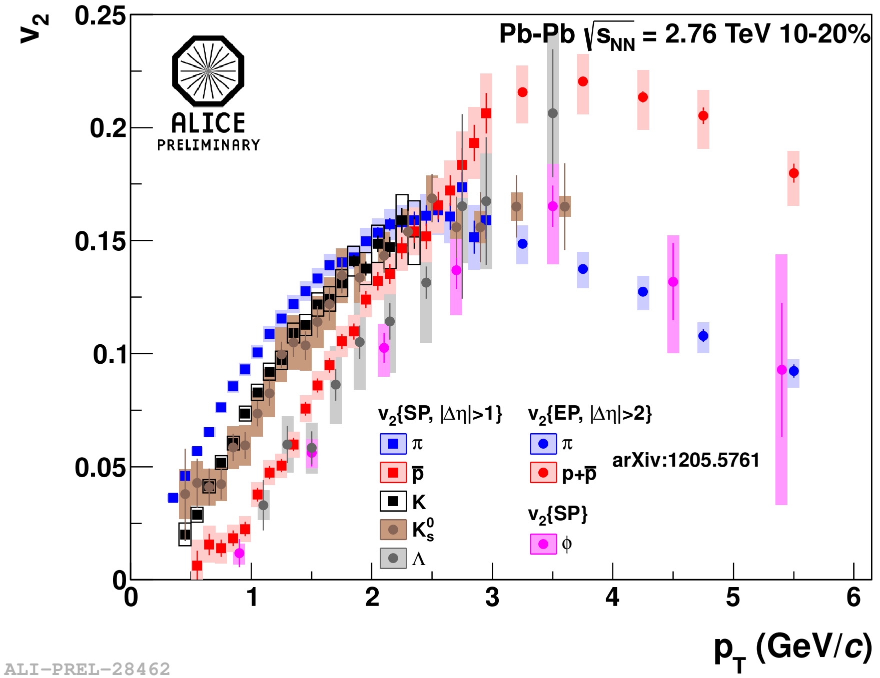
- ➢ Evident centrality dependence
- ➢ Hydrodynamic model calculation overestimates the φ-meson v_2.

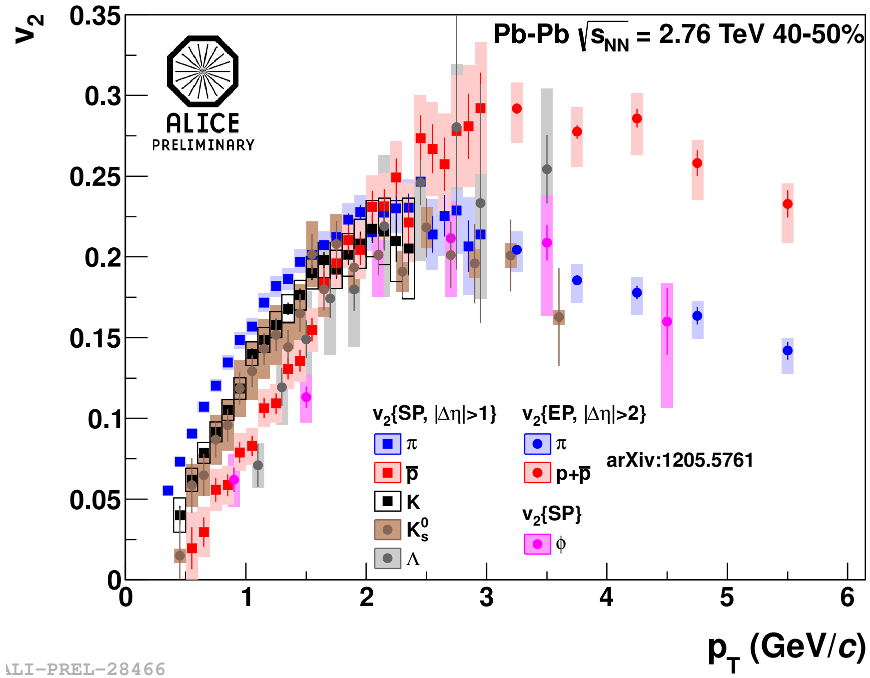
❖Results: Comparison with measurements at RHIC



- At low (high) p_T ϕ-meson v_2 is smaller (larger) compared to that measured at RHIC
- Indicates stronger radial flow at LHC

❖ Comparison with v_2 of other identified particle measured by ALICE

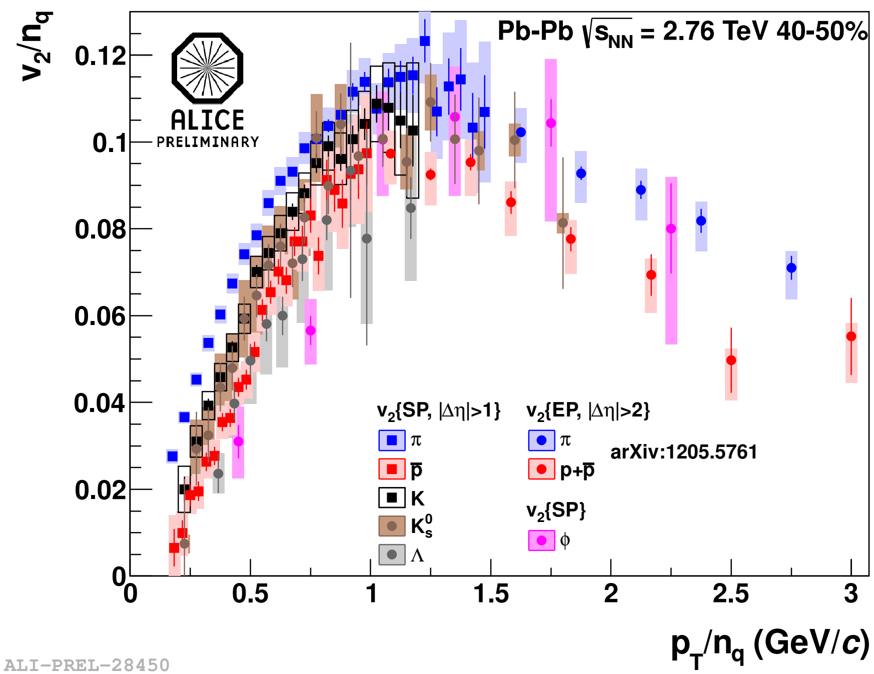




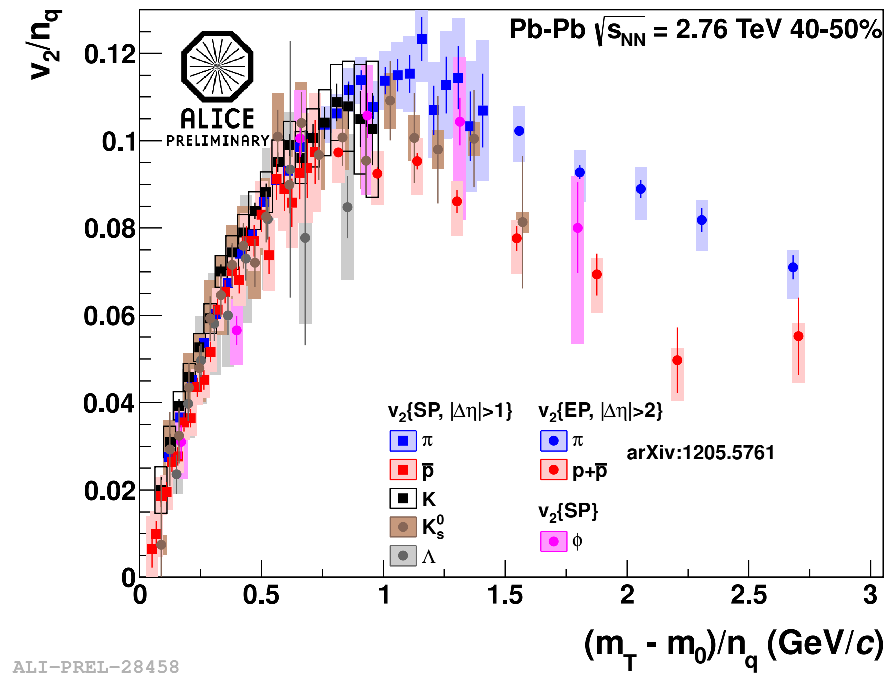
- ϕ-meson v_2 follows the mass ordering like other measured species.
- Mass dependence persists up to high transverse momenta
- At low p_T, ϕ-meson v_2 is similar to that of baryons with similar mass (anti-protons)
- At high p_T ϕ-meson v_2 is similar to that of other mesons (pions)

❖ v_2 scaling with quark number and KE_T

Number of quark Scaling (p_T)

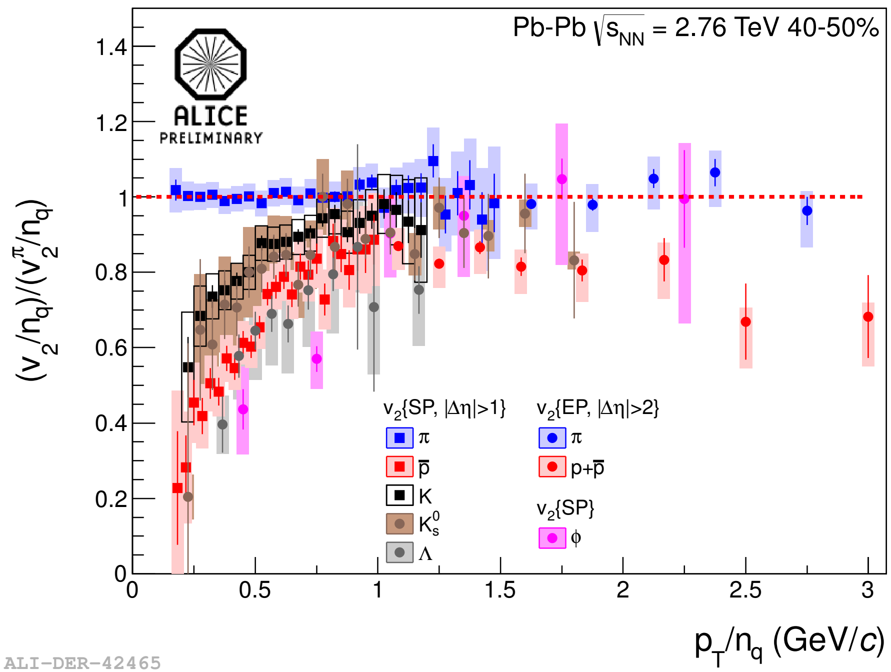


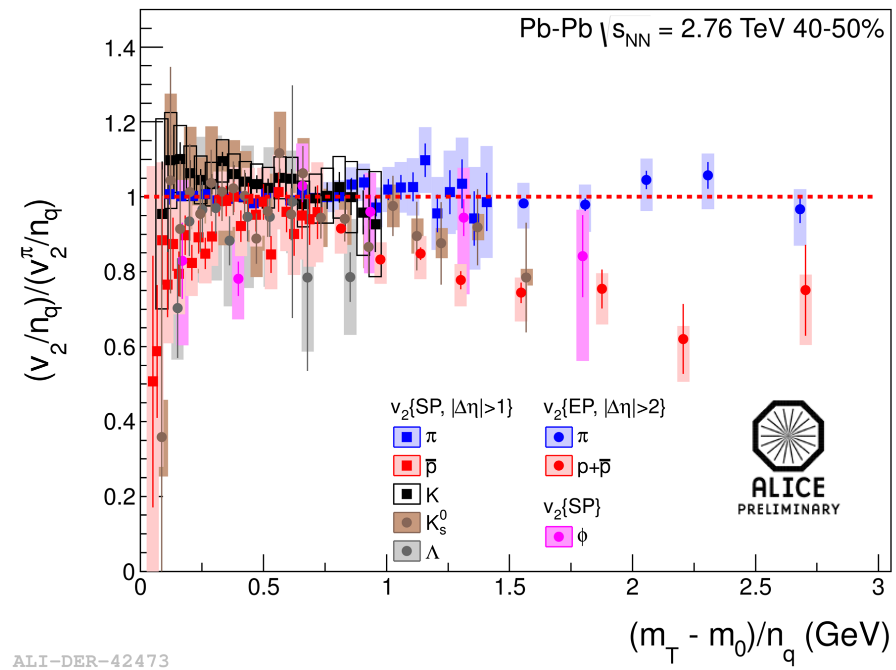
$KE_T = (m_T - m_0)$ scaling



- Compared to the observation made at top RHiC energy there are substantial deviations from the quark number and KE_T scaling

❖ v_2/n_q ratio versus p_T/n_q and $(m_T-m_0)/n_q$





- v_2/n_q vs p_T/n_q scaling holds within 20% at $p_T \sim 1.2$ GeV/c
- Low p_T/m_T: KE_T scaling is broken

❖ Summary

Elliptic flow of ϕ is measured vs. transverse momentum for different collision centrality classes for Pb-Pb collision at 2.76 TeV:

- The larger mass splitting of v_2 compared to that at RHIC points to a stronger radial flow at the LHC
- At low p_T the ϕ-meson v_2 follows the trend of other baryons and at high p_T the one of mesons.
- Number of quark scaling holds within 20% at $p_T \sim 1.2$ GeV/c
- KE_T scaling is broken at low p_T/m_T